1. Name of Experiment/Project/Collaboration: *LAr1-ND (T-1053)*

2. Physics Goals
   a. Primary: *Search for sterile neutrinos at the eV mass-scale through both appearance and disappearance oscillation channels.*
   b. Secondary: *Precision neutrino-argon cross sections with millions of interactions in the few hundred MeV to few GeV energy range.*

3. Expected location of the experiment/project: *Fermilab*

4. Neutrino source: *Booster Neutrino Beam (BNB)*

5. Primary detector technology: *LAr-TPC*

6. Short description of the detector: *LAr1-ND is the near detector in the three LAr-TPC Short-Baseline Neutrino (SBN) program on the Booster Neutrino Beam at Fermilab. MicroBooNE and the ICARUS-T600 are the intermediate and far detectors, respectively. The LAr1-ND detector will be located 110 m from the BNB target in a new on-axis enclosure directly downstream of the existing SciBooNE hall. In the LAr1-ND design, based on current LBNE concepts, a membrane-style cryostat houses a TPC with active volume 4.0 m (width) x 4.0 m (height) x 5.0 m (length), containing 112 tons of liquid argon. A high voltage cathode plane runs down the center of the volume aligned with the beam and two anode plane assemblies (APAs) are located 2 m away on either side, creating separate ionization drift regions. Each APA will hold 3 planes of wires with 3 mm wire spacing. Neighboring APA wires are jumped across the shared edge with banks of cold front-end electronics boards at the top and one vertical side of each APA. Accurate mapping of the electric field in the drift regions will be performed using a UV laser-based calibration system. The LAr1-ND design will additionally include a light collection system for the detection of scintillation light and the detector will be complemented by an external cosmic ray tagging system.*

7. List key publications and/or archive entries describing the project/experiment:
   - *M. Antonello et al., (ICARUS-WA104, LAr1-ND, and MicroBooNE Collaborations), "A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Booster Neutrino Beam," (2015),* http://sbn-docdb.fnal.gov/cgi-bin/ShowDocument?docid=269
   - *C. Adams et al. (LAr1-ND Collaboration), "LAr1-ND: Testing Neutrino Anomalies with Multiple LAr TPC Detectors at Fermilab," (2014), FERMILAB-PROPOSAL-1053.*
   - *C. Adams et al. (LAr1-ND Collaboration), "LAr1-ND: Testing Neutrino Anomalies with Multiple LArTPC Detectors at Fermilab" - arXiv: 1309.7987 [physics.ins-det], also "SnowMass 2013" White Paper (SNOW-00176).*

8. Collaboration
   a. Institution list:

Argonne National Laboratory, Lemont, IL

Universität Bern, Laboratory for High Energy Physics, Bern, Switzerland

Brookhaven National Laboratory, Upton, NY

University of Cambridge, Cambridge, UK

CERN, Geneva, Switzerland

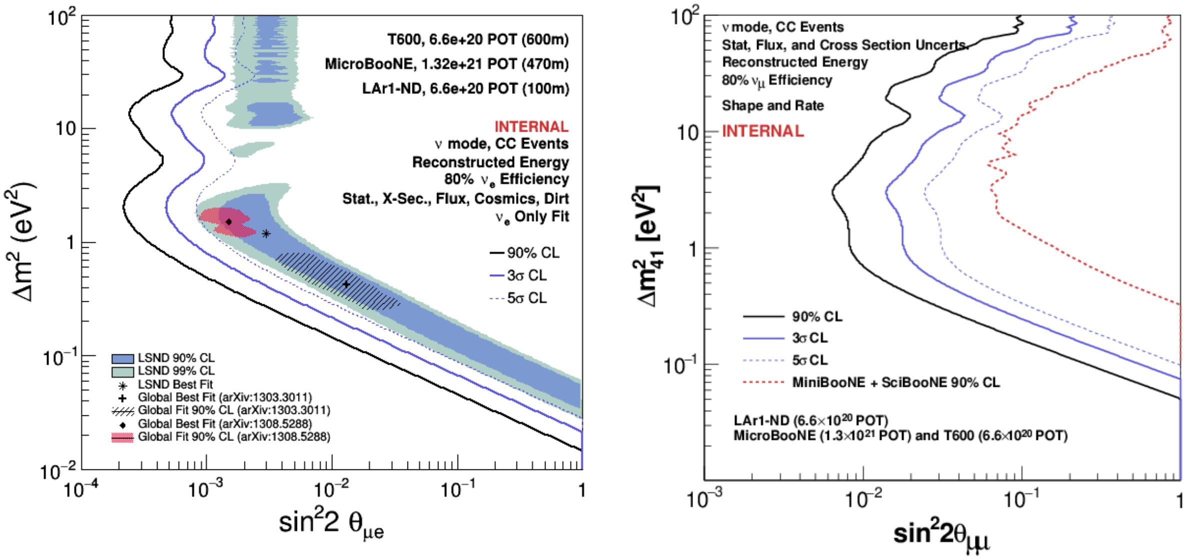
University of Chicago, Enrico Fermi Institute, Chicago, IL

Columbia University, Nevis Labs, Irvington, NY
Fermi National Accelerator Laboratory, Batavia, IL
Indiana University, Bloomington, IN
Lancaster University , Lancaster , UK
University of Liverpool, Liverpool, UK
Los Alamos National Laboratory, Los Alamos, NM
University of Manchester, Manchester, UK
Massachusetts Institute of Technology, Cambridge, MA
University of Oxford, Oxford, UK
University of Pennsylvania, Philadelphia, PA
University of Sheffield, Sheffield, UK
Syracuse University, Syracuse, NY
Center for Neutrino Physics, Virginia Tech, Blacksburg, VA
Yale University, New Haven, CT

- *b.* Number of present collaborators: *108 (including scientific and technical personnel)*
- c. Number of collaborators needed:

9. R&D
   - *a.* List the topics that will be investigated and that have been completed: *The design of the LAr1-ND detector builds on many years of LAr-TPC detector R&D and experience from design and construction of the ICARUS-T600, ArgoNeuT, and MicroBooNE detectors. Topics that will be investigated are: expanded experience in construction of membrane cryostats, development of standardized cryogenic system modules, wire plane assembly techniques, testing of next generation cold electronics, and the development of scintillation light collection systems for LAr-TPCs.*
   - *b.* Which of these are crucial to the experiment: *All are important but all new solutions adopted are intended to be improvements, not affecting the basic principle of operation of a LAr-TPC.*
   - c. Time line: *by 2017*
   - *d.* Benefit to future projects: *LAr1-ND detector design draws extensively on current designs of the LBNF far detector including cryostat technology, TPC design, and electronics, placing LAr1-ND directly on the development path to LBNF.*

10. Primary physics goal expected results/sensitivity:



Sensitivity of the SBN Program (LAr1-ND, MicroBooNE and ICARUS) to $\nu_\mu \rightarrow \nu_e$ *(Left) and* $\nu_\mu \rightarrow \nu_x$ *(Right) oscillation signals*

e. For exclusion limit (such as sterile neutrino search), show 3-sigma and 5-sigma limits *DONE*
f. For discovery potential (such as the Mass Hierarchy), show 3-sigma and 5-sigma.
g. For sensitivity plots, show 3-sigma and 5-sigma sensitivities (note that for neutrino-less double beta decay experiments that have previously been asked for 90% CL and 5 sigma limits these are OK)
h. List the sources of systematic uncertainties included in the above, their magnitudes and the basis for these estimates:
Below are listed the systematics evaluated for the full SBN Program in determining the sensitivity to oscillation signals:
   i. *Flux systematics evaluated using the highly developed Geant4-based BNB Monte Carlo built by the MiniBooNE collaboration. Hadron production cross sections and uncertainties are tied to available production data from HARP and other experiments. Primary production, secondary interactions, and focusing uncertainties are considered. Correlations between detectors have been carefully quantified and are key to the sensitivity to oscillations. After constraint, flux errors in the far detectors are ~1%.*
   ii. *Cross section systematics and correlations are evaluated using the GENIE neutrino event generator (v2.8). Due to the very high level of correlations in interactions on the same target nucleus (argon), cross section uncertainties are minimized.*
   iii. *Cosmic background estimates are based on a full cosmic flux simulation and Geant4 propagation into the detector at the surface. Systematics from cosmic backgrounds are small due to the ability to measure the rate precisely in off-beam triggers.*
   iv. *"Dirt" backgrounds are estimated using a full GENIE+Geant4 simulation of the detector in an enclosure at beam level ~7 m below grade. This background refers to beam-*

induced out-of-detector interactions that lead to energy deposits in the fiducial volume that can fake signal events (e.g. photons).

v. Detector systematics have been partially evaluated. Relative uncertainties must be kept around 2% or less. The effects studied in some detail so far have contributed at or below the 1% level.

i. List other experiments that have similar physics goals: *Many experiments are being pursued to search for sterile neutrinos through different approaches including reactors, mega-curie sources, DAR, and DIF meson beams.*

j. Synergies with other experiment: *A diverse approach, as is being pursued, is extremely important to answering this challenging question. There is a valuable synergy between pure* ν_e *disappearance searches with reactors or sources and multi-channel searches in a DIF beam such as the BNB.*

11. Secondary Physics Goal
    - k. Expected results/sensitivity: *LAr1-ND will make precise measurements of neutrino-argon interactions between a few hundred MeV and a few GeV using millions of recorded events. These measurements are valuable for the future LAr long-baseline program.*
    - *l.* List other experiments that have similar physics goals: *MicroBooNE, ICARUS, CAPTAIN-MINERvA*

12. Experimental requirements
    - m. Provide requirements (neutrino source, intensity, running time, location, space,…) for each physics goal
        - i. *Neutrino source is the Fermilab Booster Neutrino Beam*
        - ii. *Baseline intensity in sensitivity projections is 2.2e20 pot delivered per year*
        - iii. *Full SBN sensitivities are shown assuming 6.6e20 pot exposure. Cross sections and other physics measurements can already be done with a fraction of the full exposure.*
        - iv. *A new detector hall is being constructed at 110 m along the Booster Neutrino Beam*

13. Expected Experiment/Project time line
    - n. Design and development: *Dec. 2014 – March 2016*
    - *o.* Construction and Installation: *July 2015 – Oct. 2017*
    - *p.* First data: *2018*
    - q. End of data taking: *Early 2020's*
    - *r.* Final results:

14. Estimated cost range
    - s. US contribution to the experiment/project: *Funding from US DOE and NSF for the detector, electronics, cryogenics and building, expected total ~$16 M.*

t. International contribution to the experiment/project: *Major contributions to the TPC, cryogenics, laser calibration system and external muon system will come from international collaborators.*

u. Operations cost: *The sharing of operation costs for the SBN detectors will be defined in due time in a dedicated agreement, shared by all partners.*

15. The Future

v. Possible detector upgrades and their motivation: *Not yet planned, but the high rate of events in the LAr1-ND detector does make it a good venue for testing future upgrades of TPC detector components in a neutrino beam in a relatively short time.*

w. Potential avenues this project could open up: *Future running in anti-neutrino mode or beam dump mode of the BNB could be used to pursue additional physics including anti-neutrino cross sections or oscillations and dark matter candidate searches.*